SUBJECTIVE ACCEPTABLE LEVEL OF NOISE BY PEDESTRIAN ON LOCAL STREETS

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Abstract: Traffic-calming measures aim at slowing down vehicle speed, and then enhancing traffic safety and reducing traffic noise on residential streets. Speed bump is one of the most popular traffic calming countermeasures. However, sometimes, the installation of speed bump was protested by the residents in Taiwan due to traffic noise generated additionally. Therefore, this study was conducted to assess the acceptable level of noise on local streets, and furthermore, to develop the Acceptable Level of Noise (ALON) assessment model. Using Fuzzy Classification Method, the Acceptable Level of Noise is classified based on the residents' subjective feeling on the noisy traffic situation. Applying it, the Acceptable Level of Noise on local residential streets can be identified for deciding the installation of traffic calming countermeasures.

Keywords: Traffic Noise, Level of Noise, Fuzzy Classification, Traffic Calming

1. INTRODUCTION

For reducing the speed and then enhancing the traffic safety on local residential streets, there are a lot of speed bumps installed on the local residential streets in Taiwan. The Figure 1 shows an example picture in Taipei city, Taiwan.

FIGURE 1 Example of speed bump in Taipei, Taiwan

The speed bump can effect on reducing the speed both of car and motorcycle (scooter) [1]. However, in Taipei, according to the statistic of Taipei city government, there were some speed bumps removed again after installation due to being protested by the residents with the reason of traffic noise. However, the acceptance by the residents is one of the most important preconditions for successful implementation of traffic calming countermeasures on residential local streets. Benefits of safety resulted from traffic calming was proven [2]. The street designed for traffic calming is different from the traditional street design; it is to control the speed and volume [3], and then to reduce the noise. Traffic noise is naturally one of the important issues for determining traffic calming measures. Furthermore, the acceptable noise level on local streets needed to be presented for determining the installation of traffic countermeasures. Using the perceptional questionnaire survey and Fuzzy classification method [4] based on the resident perception of the noise situation, the classification the Acceptable Level of Noise is created.

2. TRAFFIC NOISE ON SPEED BUMP

Speed bump can usually reduce the vehicle speed. However, the noise by vehicle running over speed bump needs to be measured newly. According to the survey on local streets in Taipei, the noise of car and motorcycle can be reduced by speed bump, as shown in Table 1. However, what is the acceptable level by the pedestrian should be investigated further.

TABLE 1 Noise of Car and Motorcycle on the local Streets in Taipei

Vehicle type	Dimension of the speed bump	Noise of car or motorcycle on speed bump, or on the similar street without speed bump (dB(A))
Motorcycle	5 cm bump	67.11(5.02)
	2.5 cm bump	71.39 (3.75)
	1.5 cm bump	74.19 (4.08)
	No bump	73.23 (3.08)
Car	5 cm bump	66.89(4.56)
	2.5 cm bump	69.34 (4.98)
	1.5 cm bump	69.49 (4.02)
	No bump	66.80 (2.91)

Note: The value in the bracket ( )denotes standard deviation.

In order to discuss the acceptable noise level for determining the necessity of installation of speed bump, the assessment model of Level of Noise was developed further using questionnaire survey and Fuzzy Classification method.

3. CLASSIFICATION BY FUZZY CLASSIFICATION PROCESS

3.1 Classification of Acceptable Level of Noise (ALON)

In order to develop the assessment model of noise level, the concept of Level of Service similar to that in the American Highway Capacity Manual was adopted. The Acceptable Level of Noise is defined as the perceptional feeling of pedestrians on the noise generated by the car and motorcycle passing the speed bump. The Acceptable Level of Noise (ALON) is classified into 5 levels, from the best very acceptable quiet of level A to the worst very unacceptable noisy of level E. For determining these classification levels, Fuzzy Classification Process was applied [4]. Through the Fuzzy classification process, the Acceptable Level of Noise can be classified based on the perception of the road users. For the classification, the first stage is to develop the Fuzzy membership function, as shown in Figure 2.

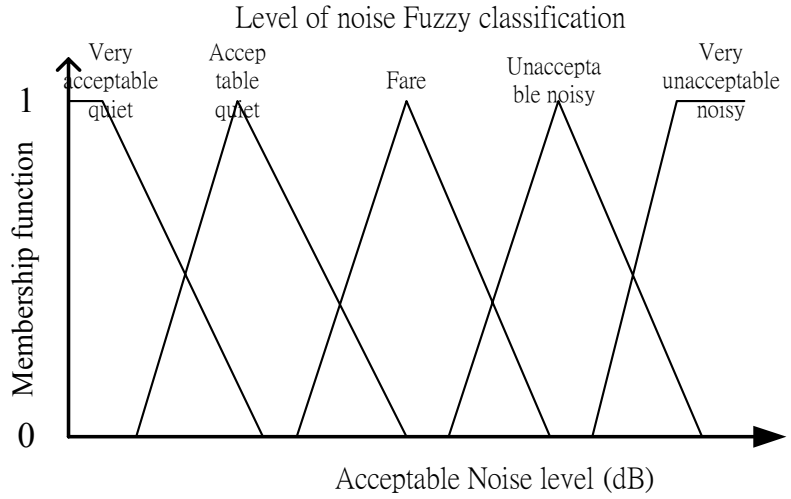


FIGURE 2 Illustration of Fuzzy classification membership function

To create the Fuzzy membership function, the first step is to conduct a survey of the perception feeling level of noise by pedestrians to determine their perception of the noise of various bump installed situations. Based on it, the Fuzzy membership functions are created, the classification threshold of every Acceptable Level of Noise (ALON) is identified.

3.2. Perception Survey of Acceptable Level of Noise (ALON)

A questionnaire survey was conducted to ask the pedestrians for their feeling on the noise. For conducting the survey, various noisy situations of the noise by the car as well as by the motorcycle driving on the residential streets with the bump as well as without the bump were

measured on the local streets. By the survey, the respondents will answer their feeling of the noise with acceptable or unacceptable level on the local streets under various traffic situations. The real traffic noise was measured on the local streets for comparing with the perceptional acceptable level of noise by the pedestrians. Through comparing the answered classification of acceptable level with the measured noise, the classification of the Acceptable Level of Noise can be classified by Fuzzy Classification Process. The various noisy situations are selected on different streets and all together have 30 cases of motorcycles and 30 cases of cars, which generate the noise on speed bump as well as on the road sections without speed bump. The noise volumes ranged from 55dB(A) to 80dB(A). Some respondents will answer very acceptable quiet by the noise of 55dB(A), might some others answer fair by the noise of 55dB(A). The respondents of this study are 42 people, in which are 19 males and 23 females. They are explained the questionnaire details in advance. Every respondent is questioned to estimate the Acceptable Level of Noise (ALON).

4. CLASSIFICATION RESULT OF ALON

There are 6 various cases for creating ALON, which are ALON of noise by car with bump, ALON of noise by car without bump, ALON of noise by motorcycle with bump, ALON of noise by motorcycle without bump, ALON of noise by all vehicles with bump and ALON of noise by all vehicles without bump. Taking the one of the 6 cases as example, which is the ALON of noise by car with bump, the process to create the classification of ALON was described as follows. The other 5 cases are following the same process to get the results illustrated together in Table 6.

1. To count the answer number of every noise level. Table 2 illustrates the survey result of the people's noise subjective response to the noise by car running over the bump.
2. To calculate the membership of each noise level answered by the respondents. Table 3 shows the result.
3. To draw the membership function, as shown in Figure 3.
4. To fit the curve for generating the curve of membership function. The curve fitting results will be used to applying the α-cut rule to find out the threshold. The results of curve fitting are illustrated in Figure 4, 5, 6, 7 and 8. The equations are illustrated in Table 4.

TABLE 2 Responses of pedestrians on the ALON of Noise by Car with Speed Bump

Range of Noise volume(dB)	Average Noise volume(dB)	ALON A (very quiet)	ALON B (quiet)	ALON C (ordinary)	ALON D (noisy)	ALON E (very noisy)	Total sample
55~60	57.5	61	64	37	6	0	168
60~65	62.5	32	175	119	10	0	336
65~70	67.5	4	65	345	90	0	504
70~75	72.5	0	8	46	140	16	210
75~	77.5	0	0	5	16	21	42
Total		97	312	552	262	37	1260

TABLE 3 Membership of ALON of Noise by car on Speed Bump

Range of Noise Volume (dB(A))	Average Noise Volume (dB(A))	ALON A (very acceptable quiet)	ALON B (acceptable quiet)	ALON C (fare)	ALON D (unacceptable noisy)	ALON E (very unacceptable noisy)
55~60	57.5	1	0.9531	0.5781	0.0938	0
60~65	62.5	0.1829	1	0.68	0.0571	0
65~70	67.5	0.0116	0.1884	1	0.2609	0
70~75	72.5	0	0.05714	0.3286	1	0.1143
75~	77.5	0	0	0.2381	0.7619	1

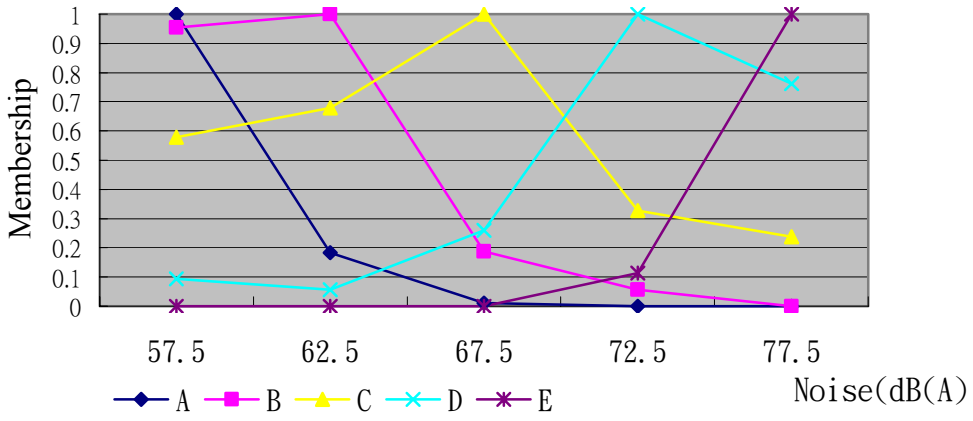


FIGURE 3 Membership of ALON of Noise by Car with Bump

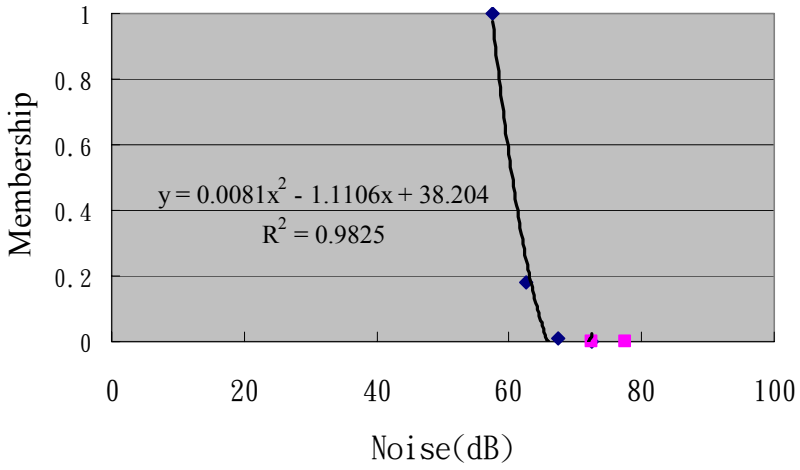


FIGURE 4 Membership Function of ALON A of Noise by Car with Bump

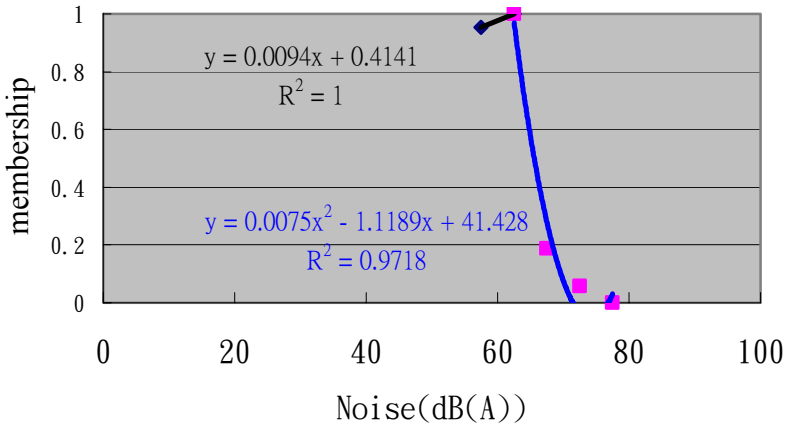


FIGURE 5 Membership Function of ALON B of Noise by Car with Bump

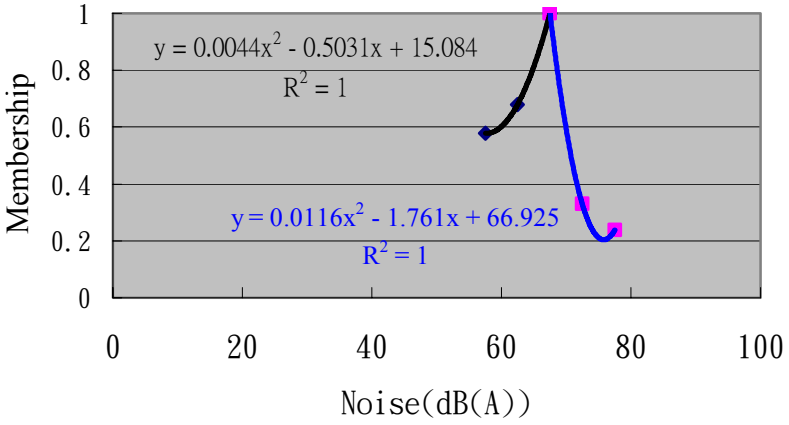
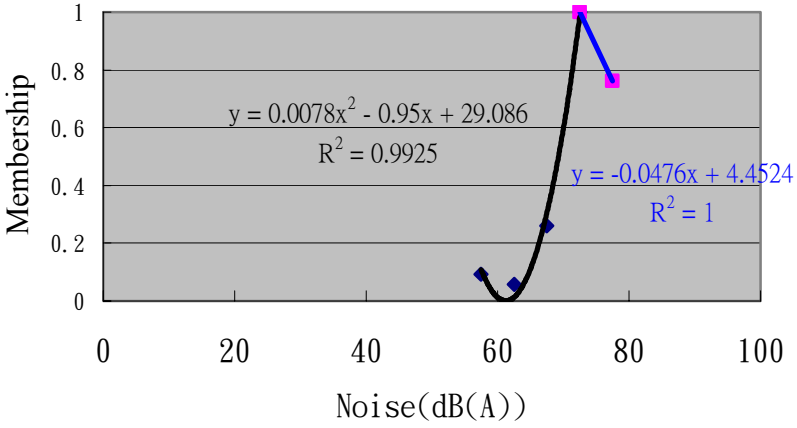


FIGURE 6 Membership Function of ALON C of Noise by Car with Bump



FIGHURE 7 Membership Function of ALON D of Noise by Car with Bump

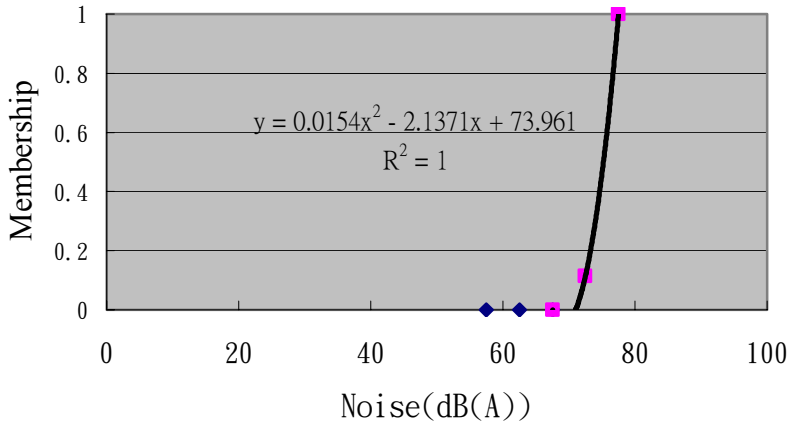


FIGURE 8 Membership Function of ALON E of Noise by Car with Bump

TABLE 4 Membership Functions of ALON Level of Noise by Car with Bump

Acceptable Level of Noise（ALON）	Membership function	R^2	Range of volume
A (Very acceptable quiet)	$y=1$	1	$x=57.5$
	$y=0.0081x^2-1.1106x+38.204$	0.9825	$57.5<x<72.5$
	$y=0$	1	$72.5\leq x$
B (Acceptable quiet)	$y=0.0094x+0.4141$	1	$57.5<x<62.5$
	$y=1$	1	$x=62.5$
	$y=0.0075x^2-1.1189x+41.428$	0.9718	$62.5<x<77.5$
	$y=0$	1	$77.5\leq x$
C (Fare)	$y=0.0422x-1.884$	0.9182	$57.5<x<67.5$
	$y=1$	1	$x=67.5$
	$y=0.0116x^2-1.761x+66.925$	1	$67.5<x<77.5$
D (Unacceptable noisy)	$y=0.0078x^2-0.95x+29.086$	0.9925	$57.5<x<72.5$
	$y=1$	1	$x=72.5$
	$y=-0.0476x+4.4524$	1	$72.5<x$
E (Very unacceptable noisy)	$y=0$	1	$57.5<x\leq 67.5$
	$y=0.0154x^2-2.1371x+73.961$	1	$67.5<x<77.5$
	$y=1$	1	$77.5\leq x$

For creating the boundary of each ALON, the α-cut rule is adopted to find out the threshold. The α-cut rule means to set the membership of α, e.g. 0.9, as the threshold. The noise value of the membership function with membership of o.9 will be taken as threshold. The best results come from α=0.9, because there is no overlap between different Levels of Noise. The resulted noise level of each Level of Noise is illustrated in Table 5.

TABLE 5 The Boundary Noise Value of ALON of noise by Car with Bump by（α=0.9）

ALON	A		B		C		D		E	
Boundary	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
	**	58.84	51.69	61.93	65.97	67.55	70.64	74.63	77.77	**
Interval boundary	**	55.27		63.95		69.10		76.20		**

5. RESULT OF ALON AND APPLICATION

For the cases of car, as well as of the motorcycle under with bump and without bump conditions, all the ALON membership functions and thresholds are created following afore mentioned Fuzzy Classification Process. The results are illustrated in Table 6. Comparing the result of different cases, based on the ALON of E level, the boundary noise value without bump is greater than the boundary value with bump. In the case of car, the boundary value of noise at the E level is 76.2 as without bump and 75.4 as with bump. In the case of motorcycle, the boundary value of noise at the E level is 77.8 as without bump and 76.95 as with bump.

TABLE 6 Comparison of the ALON Level of Noise under Different Traffic Situations

ALON Level of Noise	Noise by car (dB(A))		Noise by motorcycle (dB(A))		Noise by all vehicles (dB(A))	
	Without bump	With bump	Without bump	With bump	Without bump	With bump
A (very acceptable quiet)	≦55.3	≦55.0	≦ 55.0	≦ 55.0	≦56.3	≦ 55.0
B (acceptable quiet)	≦63.9	≦64.3	≦64.9	≦63.7	≦64.6	≦63.8
C (fare)	≦69.1	≦72.3	≦75.2	≦74.9	≦ 68.8	≦73.3
D (unacceptable noisy)	≦76.2	≦75.4	≦77.8	≦76.9	≦78.7	≦74.8
E (very unacceptable noisy)	> 76.20	> 75.4	> 77.8	> 76.9	> 78.7	> 74.8

In the case of all vehicles combined, the boundary value of noise at the ALON E level of noise is 78.7 as without bump and 74.8 as with bump. Even the difference is only slightly, the results depicts when the resident can afford less noise level and feel much noisier under the similar noise level when the street has no speed bump. The acceptable level of noise of motorcycle is slightly greater than the level of car.

Applying the classification model of ALON in Table 6, the level of noises perceived by the pedestrians on the local streets resulted from the field measurement of noises, as shown in Table 1, are illustrated in Table 7.

TABLE 7 Assessment of the ALON Level of Noise of the Survey of Table 1

Vehicle type	Locations with the type of speed bump.	Noise of car or motorcycle on speed bump, or on the similar street without speed bump (dB(A))	ALON: A (Very acceptable quiet); B (Acceptable quiet) C (Fare) D (Unacceptable Noisy) E (Very unacceptable Noisy)
Motorcycle	5 cm bump	67.11(5.02)	C
	2.5 cm bump	71.39 (3.75)	C
	1.5 cm bump	74.19 (4.08)	D
	No bump	73.23 (3.08)	D
Car	5 cm bump	66.89(4.56)	C
	2.5 cm bump	69.34 (4.98)	C
	1.5 cm bump	69.49 (4.02)	C
	No bump	66.80 (2.91)	C

Taking for local streets as example, the level of noises are assessed. These four local streets have not installed the speed bump. The field measured results of noise are 73.1, 72.33, 74.71 and 73.23 dB(A) in average of all vehicles. The ALON level of noise felt by the pedestrians are classified as unacceptable D, D, D and D level. It is at unacceptable noisy level. On those streets, the speed bump should be installed, better with the height of 5cm. The noise is expected to be reduced to about 67 dB referred to Table 1. The ALON level of noise will be improved to be fare C level

6. CONCLUSION

Motorcycle drives on local residential streets usually with higher speed than car. Motorcycle usually generates higher noise than the car. Considering reducing noise by traffic calming countermeasures, the motorcycle is to be most concerned. The speed bump higher than 5cm will effect on reducing the speed and noise by motorcycle very effectively. In general, the noise of motorcycle and car passing through the streets with speed bump is smaller than the noise generated on the road section without speed bump. According to the research results in the study, most of the local streets without speed bump have the noise more than 70 dB. It needs to be improved by installing the speed bump. It can be reduced to 67 dB. If the noise has to be reduced to be less than 67 dB, it is difficult to be achieved by installing speed bump. It is better to consider the other traffic calming countermeasures. The Acceptable Level of Noise developed in the study can be applied to identify the noise level of the streets perceived by the pedestrians. It can applied to determine if it should be setup traffic calming countermeasures to reduce the noise or not. It is expected to be useful practically.

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